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Application of anaesthetics in South American camelids - current knowledge

Diploma thesis

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Wien, 28.05.2024 Casper Bester

SUMMARY

The study aimed to compile information on indications, pre anaesthetic considerations, drug use, and general management regarding an anaesthetic intervention in South American camelids (SACs) by means of a literature review. A literature search was conducted, where original research papers, books, conference proceedings and case reports on the topic were identified. Based on EU Regulation 37/2010 only papers describing the use of drugs authorized for “food producing animals” were highlighted. The data was exported into an Excel file and analysed for the described content. The evaluated and applied anaesthetic protocols, appear to be safe for the use in SACs. Alpha-2 adrenoceptor agonist xylazine and detomidine, the opioid butorphanol, ketamine, isoflurane and local anaesthetic drugs were discussed in detail. Protocols using an alpha-2 adrenoreceptor agonist in combination with an opioid as premedication and ketamine for induction appear to be safe in healthy animals considering the advised dosages. No contraindications for the use of local anaesthetics in SACs were found in this literature search. In conclusion, literature is sparse and incomplete. Further studies, exploring different protocols and other drug classes would be beneficial, to further the knowledge on safe anaesthetics and to develop guidelines on anaesthetic protocols safe for the use in both healthy and compromised SACs.

ZUSAMMENFASSUNG

Auf Grund zunehmender Populationsgrößen von Neuweltkameliden in Europe, hat diese Studie bestehende Literatur zum Thema Anästhesie bei Neuweltkameliden gesichtet, analysiert und im Rahmen einer Literaturarbeit zusammengefasst. Es wurden dabei sowohl publizierte Bücher, wissenschaftliche Studien als auch Fallberichte berücksichtigt. Um die umfangreichen Aspekte der Anästhesie abzudecken, wurden in der Analyse die Indikationen, prä-anästhetischen Überlegungen, Medikamentenauswahl, allgemeines Management während der Anästhesie als auch Komplikationen berücksichtigt. Neuweltkameliden werden in Europa als Lebensmittel liefernde Tiere klassifiziert. Da in Europa die EU-Verordnung 37/2010 festlegt, welche Medikamente für Lebensmittelliefernde Tiere verwendet werden dürfen, bildet diese Rechtsgrundlage die Basis für die zu analysierenden Medikamente. Die erworbenen Daten wurden zusammengetragen und deskriptiv analysiert. Genauer analysiert wurden die folgenden Medikamente: Alpha-2 Adrenozeptor Agonisten Xylazin und Detomidin, Ketamin, Butorphanol, Isofluran und Lokalanästhetika, wie Lidocain. Die in den Studien und Fallberichten angewendeten Protokolle erscheinen für den Gebrauch in Neuweltkameliden sicher zu sein. Für Europa relevante Kombinationen und Protokolle, die Xylazin gemeinsam mit Ketamin und Butorphanol verwenden, scheinen in gesunden Tieren unter Berücksichtigung der empfohlenen Dosierungen zu keinen nennenswerten Nebenwirkungen zu führen. Zusammenfassend kann man sagen, dass die vorhandene Literatur lückenhaft ist und vor allem wenig Schlüsse in Bezug auf kranke oder komprimierte Tiere zulässt. Weitere Forschungen und Studien, die verschiedene Protokolle, auch für kranke Tiere analysieren, wären zukünftig hilfreich, um Richtlinien für praktizierende Tierärzte sowohl für gesunde als auch für gesundheitlich komprimierte Tiere formulieren zu können.

ABSTRACT

The present study aimed to collate available literature on safety and efficacy of anaesthetic drugs in South American camelids (SACs).

The growing populations of SACs kept in private holdings, demands increasing awareness and knowledge by the veterinary professionals on safe drug use, side effects, pre anaesthetic considerations and management during peri anaesthetic phase as well as the recovery period. SACs in Austria is considered a food-producing animal, therefore the available medications are limited to the licenced drugs listed in the EU regulation 37/2010.

A literature search was conducted, whereby original research papers, books, conference proceedings and case reports were considered. The identified literature was collated and data was extracted into an excel file for further analysis and data description.

In total, 16 original research papers, 5 books, 4 conference proceedings, 1 review, 4 summaries and 36 individual case reports were screened for essential data. Most frequent indication for anaesthetic intervention was an abdominal and orthopaedic surgery. Literature is inconsistent regarding time of fasting period, reaching from 12 up to 48 hours. Little information is available concerning equipment and intubation technique.

In conclusion, literature is sparse and incomplete. Further studies, exploring different protocols and other drug classes would be beneficial, to further the knowledge on safe anaesthetics and to develop guidelines on anaesthetic protocols safe for the use in both healthy and compromised SACs.

Content

1. Introduction

South American camelids (SACs) can be differentiated into wild species, namely the vicuna (*Vicugna vicuna*) and the guanaco (*Lama guanicoe*), while the alpaca (*Lama pacos*) and the llama (*Lama glama*) are considered as domesticated species (1). Hybrid crossbreeding of alpacas and llamas is possible and their offspring are so called huarizos (2). Originally, SACs were domesticated due to their importance as source of food and for their use as pack animals (2). Subsequently other traits, such as their wool or skin, became important as well. Today, in Europe, most SACs are kept as pets or for leisure activities, i.e., walking or trekking-tours (2–4). Since SACs naturally produce wool, most alpaca owners (>60%) still use their wool for further production (2,3,5). Additionally, more than 50% of these SAC holders keep their animals for breeding purposes and shows (2).

1.1. Population in Europe

In Europe, the number of privately kept SACs has increased significantly during the past decades (4,6–8). A marked increase in the SAC population in Austria has been observed over a period of 30 years (9,10). Statistics on the number of SACs in Austria currently suggests, that there are about 11,000 SACs (9–11) spread across all nine counties in Austria (2), which suggests a ten-times increase since 2006. Today, in Austria, herd sizes vary between 5 and more than 70 animals, whereby the majority of the population is represented by adult female alpacas (2,3). Llamas are kept in smaller herds in comparison to alpacas and the largest herds are found in Styria and Upper Austria, consisting of more than 20 animals (2).

1.2. Veterinary Care for SACs

The majority of SAC herds receive regular veterinary care (5). Injuries, lameness, or dental problems occur in less than 10% of farms at least once a year (5). However, symptoms or diseases of the gastrointestinal system, i.e. diarrhoea, wasting, emaciation (5,12) were reported to be the most common causes for owners to seek veterinary advice (13), which are also the most common pathological findings as cause of death in SACs (12). Other symptoms or conditions requiring veterinary assessment are for example skin problems, abnormalities of the eye, symptoms affecting the cardiovascular systems or the reproductive system (5,13). The ruminant clinic at the University of Veterinary Medicine in Vienna (UVMV) has treated 634 SACs between 2005 and 2019 (11). Likewise, as the general population of SACs has increased, the UVMV has noted a significant increase in animals presented to the clinic (14). Orthopaedic case presentations are common, however gastro-intestinal diseases also requiring surgical attention have likewise become more frequent (15). Similar findings could also be observed at the UVMV, which recorded 44% of patients with orthopaedic diseases and 8% of patients with abdominal issues in 2010, while in 2018 22% were presented for abdominal diseases and 30% for orthopaedic reasons (14). Furthermore, dental issues, skin issues and routine procedures, which simply provide care or are regarded as prophylactic treatment, are frequent reasons for a visit to the university clinic (2,14).

1.3. Sedation and anaesthesia in SACs

Based on the variety of symptoms or diseases presented, beside a thorough clinical examination, there is a need for routine clinical diagnostics, such as radiographs, endoscopy, or computer-tomography but also for interventions, surgical procedures, non-surgical procedures and adequate treatment. Based on the intervention, sedation, or general anaesthesia (GA) is required (16). Whether a scheduled routine procedure or an emergency procedure is carried out on a SAC, the requirement for safe anaesthetic protocols and a sufficient management is evident. Surgical procedures often require GA, which encompasses the following three aspects, i.e., plus / minus analgesia, plus / minus muscle relaxation and unconsciousness, which is also called the triad of anaesthesia (17). Sedation must be distinguished from GA since it usually doesn't provide unconsciousness, but tranquilisation. Hence, sedation and GA are two different medical techniques and must be considered as such, but for both the triad can be applied. Therefore, when choosing to do procedures under solely sedation compared to GA one needs to consider the advantages, disadvantages and indications for both options. Seeing as sedation is considered as a continuum (18,19) it is difficult to assess to which depth each patient will respond. Sedation is often used for its ability to decrease stress in a patient making them easier to be handled (20,21). Besides, sedatives are known to reduce the amount of other anaesthetic drugs when used during premedication, to provide balanced anaesthesia (19). Dose dependant sparing effects of the premedication reduces the needed dosage of the induction drug, which are delivered intravenously (IV). While some anaesthetic drugs such as alpha-2 adrenoceptor agonists provide both sedation, muscle relaxation and analgesia (16,22), other drugs have only analgesic or anaesthetic components (i.e., ketamine). Therefore, to provide good sedation or GA with minimal risk, appropriate drug combinations must be applied to cover all aspects of the triad of anaesthesia or sedation.

In SACs, sedation is often preferred and sufficient for veterinary procedures like toe trimming, teeth trimming, handling of wild or aggressive animals, ultrasound, minor surgeries, and procedures as for example stitch ups (22,23). While under mild to deep sedation an animal remains conscious, it is advised to evaluate a minimal database of body temperature, heart rate and rhythm, respiratory rate, and character as well as the animal's clinical demeanour (23) before attempting to sedate a SAC. As one moves into deeper sedation the need for further monitoring and supplementation of oxygen becomes more apparent as increasing depression of respiratory and cardiovascular system is commonly noted (18,22). Thus, GA must be utilized in more invasive procedures, requiring unconsciousness for example large laceration stitch ups, tooth extractions, fracture repairs or abdominal surgeries (22).

1.4. Pre anaesthetic considerations

Blood work

It is advised to monitor essential parameters throughout GA, however, full blood count, information on packed cell volume as well as total protein should be obtained prior to a planned GA in a SAC (22,23). Further, the age and general health status of the patient, and indication for GA should also be considered to decide whether additional bloodwork, i.e., biochemistry, fibrinogen levels or further diagnostic tests would be of value before anaesthetizing the patient (22).

Fasting

Camelids produce large amounts of saliva; thus, they can be more prone to regurgitation which in turn can lead to aspiration and pneumonia (20). Reducing the risk of regurgitation can also be targeted by fasting patients prior to planned sedations or GA. Recommendations are that animals over the age of 4 months be held off feed for the duration of 12-18 hours (20,22) though some recommendations suggest even periods up to 24 hours (21,23) or up to 48 hours (16) before commencing anaesthetic procedures. Some literature suggests removing access to water 8-12 hours prior to any procedures (16,23) however the need to fast water is not everywhere supported (22).

1.5. Local anaesthesia

Reducing post-operative stress and pain should already be considered in the choice of pre-medication and throughout anaesthesia. In addition to systemic analgesic drugs, use of local anaesthetics is indicated for many different procedures. It is an effective and affordable way to provide a great pain relief (22) with minimal side effects (24). The use of local anaesthetic drugs enables a drug-sparing effect on the general anaesthetic protocol and in some cases can facilitate procedures such as castration (20,23), wound care (20), or thoracocentesis (20). Due to transmission being blocked, which is the conductance of pain impulses from the peripheral nociceptors to the dorsal horn neurons within the spinal cord, use of local anaesthetics makes central sensitisation less likely (22). However, local anaesthetics are not as often used for regional nerve blocks as in small animal medicine (16,20). Local anaesthetics alone might be used to place an intravenous catheter in patients which are used to handling and do not require sedation beforehand (23). Lidocaine, originally an anti-arrhythmic drug, and procaine are commonly used as local anaesthetic drug or for epidurals (16,20). Epidurals are useful in any perianal surgeries, surgeries of the hind limb, reproductive surgeries or in a case of dystocia (20,24,25). Complications associated with local anaesthesia are usually not reported when used properly.

1.6. Licenced narcotics for SACs in Austria

Since SACs are considered by law as food producing animals only specific drugs, which are labelled for the use in livestock are licenced for the application (26). While for small animals a large variety of anaesthetic, sedative or analgesic drugs is available to adapt the anaesthetic protocol to the needs of the individual patients (27), the number of licenced drugs for SACs is limited. However, additional drugs, and their respective active ingredients, which are not labelled for their use in food animals, can be repurposed in accordance with the Austrian regulation for the veterinary drug control act (28). To adhere to the legislation, an appropriate time period, to allow for the drug to be metabolized before the animal would qualify for slaughter, has to be appointed by the acting veterinarian (28).

According to government and EU regulations the allowed drugs for anaesthesia in SACs are xylazine, detomidine, ketamine, butorphanol, lidocaine, procaine, and isoflurane (28). However, the list of these drugs is not exhaustive regarding anaesthetic drugs used in SACs. Other drugs described and used according to literature are different alpha-2 adrenoceptor agonists like medetomidine or benzodiazepines such as diazepam and midazolam, different opiates as well as guaifenesin (22) all of which are not allowed to be used in SACs in European union according to legislation (26).

To be able to look at which drugs and dosages are advised as well as which are proven to be best applied, one first has to look at their pharmacokinetics and pharmacodynamics to see how they truly function. Literature describes the pharmacokinetics of a drug as the study of its disposition as well how its concentration changes within the body over time (22). In short, this equates to the estimated amounts of the rate and extent of distribution, elimination, and absorption of a drug which then predicts the plasma drug concentrations within individuals or groups of animals (22). Pharmacodynamics describes the relationship of the drug exposure, be it the concentration or dose, and its pharmacological response (29). It is thus the relationship of the drug concentration at its site of action as well as its biochemical and physiological effects (30).

While clinical examinations, bloodwork and further diagnostics aim to identify patient individual risk factors to allow identification of safe anaesthetic protocols, awareness of common complications is important to be able to respond correctly if they occur. Sound knowledge on the safe dosages, pharmacokinetics and pharmacodynamics in the species are therefore paramount to provide gold-standard medical care for the animals.

1.6.1. Alpha-2 adrenoceptor agonists

Xylazine belongs to the family of alpha-2 adrenoceptor agonists and is typically used for its sedative, analgesic, and muscle relaxant properties (16,20). Xylazine results in dose-dependent sedation and analgesia thus making it a good choice in uncooperative patients (22). Dose dependency means that recumbency can be achieved at higher doses (24). Because camelids are more resistant to the sedative effects of xylazine compared to ruminants, the level of sedation produced by a given dose therefore varies noticeably (22).

Detomidine is a non-narcotic sedative, analgesic and alpha-2 adrenoreceptor agonist (16) with an increase in duration of effect compared to xylazine (16,20,31). Thus, it has a higher potency resulting in a more prominent decrease in heart rate as well as reduced cardiac output (22). Detomidine does however increase blood pressure when given IV as compared to xylazine (22). Besides, the same complications are known to occur with the use of detomidine as with the active ingredient xylazine (16,22).

Alpha-2 adrenoceptor agonists are associated with an increase in arterial blood pressure due to the resulting vasoconstriction. The heart rate decreases due to a baroreceptor reflex caused by the increased blood pressure and a reduced sympathetic outflow from the central nervous system (20). Respiratory depression can also be seen, which can result in apnoea (20). Additional side-effects are a decrease in cardiac output as well as aortic flow, impaired thermoregulation (16) and an increase in urine production due to reduced effects of the antidiuretic hormone (20). Because of significant effects to the cardiovascular system as well as the gastrointestinal tract its administration should always be used after careful consideration (22). Due to a potentially reduced uterine blood flow, it is not advised to use the drug in pregnant animals (22).

1.6.2. Ketamine

Ketamine is a N-methyl-D-aspartate (NMDA) receptor antagonist which is widely used in different species for induction of anaesthesia (32). Ketamine does not provide excellent muscle relaxation, hence should only be used in combination with other drugs like alpha-2 adrenoreceptor agonists (32). Because ketamine is a nonbarbiturate dissociative agent (16), in higher dosages it can cause the retention of normal pharyngeal-laryngeal reflexes which in turn can hinder intubation (16,20). Additionally, it initiates a state of catalepsy which results in the fixed expression of the eyes causing eyelids to remain open throughout anaesthesia. Damage to the cornea is a risk, which is associated within several drugs used for anaesthetic interventions (16,20). Ketamine can result in tonic-clonic convulsions; however, this side effect has not been observed after intramuscular (IM) or IV injection in camelids (16,20).

Ketamine produces analgesia at the NMDA-receptor even at subanaesthetic doses, which is important for prevention of hyperalgesia (31). The active ingredient is metabolized in the liver and excreted through the kidneys (16,20). It is important that when ketamine is given IV it is done at a slow rate as it can cause apnoea if given too rapidly (16,20). Although ketamine is given quite often via the IM route, animals do experience transitory pain upon its administration hence in most studies it is given via the IV route. (16,20). Additionally, ketamine is not known to produce abortion even though it is proven to cross the blood-placenta barrier (16,20).

1.6.3. Butorphanol

Butorphanol is an analgesic κ-agonist, μ-antagonist opioid that can result in sedation or increase the sedative effects of other drugs, for example xylazine (20). It can be administered in various ways; IV, IM or subcutaneously (SC) in doses up to 0.1 mg/kg in llamas (20,23) and up to 0.2 mg/kg in alpacas (23). Butorphanol at these dosages results in a mild level of sedation in camelids (22). Use on its own does not usually results in recumbency. However, sedation is more pronounced with IV administration compared to IM (22). It generally facilitates the handling of the animal, but other drugs are required for more painful procedures as its systemic analgesic efficacy is limited (16,22). The drug also has a slow time of onset with IV administration being 10 minutes and IM 20 minutes respectfully (22). Known side effects should be considered. Butorphanol, similar as other opioids, has been shown to reduce the gastrointestinal motility if administered in high dosages or over a longer period of time (33,34).

1.6.4. Isoflurane

Isoflurane is the only registered inhalant anaesthetic agent for SACs in the European union (26), besides it is inexpensive and universally used (20). However, desflurane and sevoflurane have been used in camelids as well (21). The minimum alveolar concentration (MAC) of isoflurane for adult llamas has been determined to be 1.05 +- 0.17% (20). The MAC has not been determined for adult alpacas specifically, but it is hypothesized to be similar to that for llamas (20). Isoflurane has a quick onset of action and results in a quick recovery from anaesthesia (22). Muscle relaxation under inhalation anaesthetics is deemed adequate for the completion of most if not all procedures (22). Isoflurane's haemodynamic effect, namely vasodilation is the most common side effect of the inhalation anaesthetic drug which is dose-dependent and can in turn lead to hypotension (21,22). Additionally, respiratory depression can frequently be observed in patients which are maintained under GA by the use of this drug (20,22). Blood pressure monitoring is therefore recommended in all animals which receive an anaesthetic gas (20,22).

Due to the continuously increasing numbers of SACs in Austria, as seen by data, compiled knowledge on indications for anaesthetic interventions, management in different phases of an anaesthetic intervention and safe use of drugs is needed to provide the required evidence-based veterinary services at low risk for the animal. Since many areas regarding anaesthesia in SACs are yet to be researched, no claim regarding conclusiveness can be made at this point. However, existing data on anaesthesia in SACs should be considered as a current baseline to inform practitioners in the field and in clinics on drug effectiveness, safety and usage.

The goal of this literature review is to determine the extent of published knowledge dealing with anaesthesia in SACs. Due to the national legislation this study will focus on anaesthetic drugs licenced for their use in food-producing animals in the European union.

2. Material and Methods

For the descriptive literature review peer-reviewed articles were searched in “Google Scholar” and “PubMed”. The following terms were used to identify relevant literature: “anaesthesia in new world camelids”, “anaesthesia alpaca”, “anaesthesia vicuna”, “anaesthesia llama”, “sedation alpaca”, “sedation vicuna”, “sedation llama”, “anaesthesia protocol and new world camelids”, “anaesthesia protocols and alpaca”, “anaesthesia protocol and vicuna”, “anaesthesia protocols and llama”. Only papers published in English were selected for the purpose of this diploma thesis. The literature search was conducted in July, 2023.

Book chapters, scientific articles, and congress proceedings were considered for this diploma thesis. First author, publication year and affiliation of first author (country) were documented. It was differentiated between a scientific study using a specific study design and a case report. The following parameters were evaluated:

Scientific study:

- Animals (species, number, age, gender, weight)
- Preanesthetic parameters: blood work, fasting, sedation/premedication, local anaesthesia
- Anaesthetic parameters: induction of anaesthesia: use of anaesthetics (dosage, way of administration), intubation, position of animal during anaesthesia, monitoring
- Postanaesthetic parameters: recovery time
- Duration

Case report:

- Indication for anaesthesia (surgical indication)
- Animals (species, number, age, gender, weight)
- Preanesthetic parameters: blood work, fasting, medical treatment, sedation/premedication, local anaesthesia
- Anaesthetic parameters: use of anaesthetics (dosage, way of administration), position of animal during anaesthesia, monitoring
- Postanaesthetic parameters: recovery time
- Duration

3. Results

3.1. Literature findings

In total, 66 sources were analysed using the specified search terms: 5 books, 4 congress proceedings, 16 original research papers, 1 review, 4 summaries and 36 published case reports.

The five books were published between 2010 and 2022 in the USA. Out of the four congress proceedings (1991-2004), three were from the USA and one from Belgium. Only one of the congress proceedings included sufficient information to be included to the analysis of the 16 research papers. The review (2005) was published in the USA as well as the four summaries (1999-2011).

The 36 case reports were published between 1991 and 2022. Of these case reports, 11 (30.5%) originated in the USA; seven (19.4%) were done in Australia; seven (19.4%) in the United Kingdom; three (8.3%) were from Switzerland, three (8.3%) were from Belgium and three (8.3%) were from Canada. One case study each was reported from Austria (2.7%) and Italy (2.7%). Those case reports described 56 individual cases undergoing anaesthesia.

The 16 original research papers were published between 2001 and 2023. The majority of the research studies were conducted in the USA (93.8%, n=15) and one was done in Australia.

Not all research papers clearly stated which type of study was conducted. Eight studies were randomized, while one was classified as not randomized. Six studies were crossover studies, seven were prospective and two were listed as blinded studies. Different combinations of the different study types were represented. A variety of different research questions were analysed. Five of the 16 (31.3%) research papers evaluated the cardiopulmonary effects of the drugs used within their protocols. A further six (37.5%) studies looked at the pharmacokinetics and dynamics of different drugs. Two papers (12.5%) reported the use of different sedation or anaesthesia protocols, while another two studies (12.5%) evaluated also the analgesic effects of specific drugs. Different indication field for anaesthesia were represented within the case reports (Figure 1) applying patient individual anaesthetic protocols.

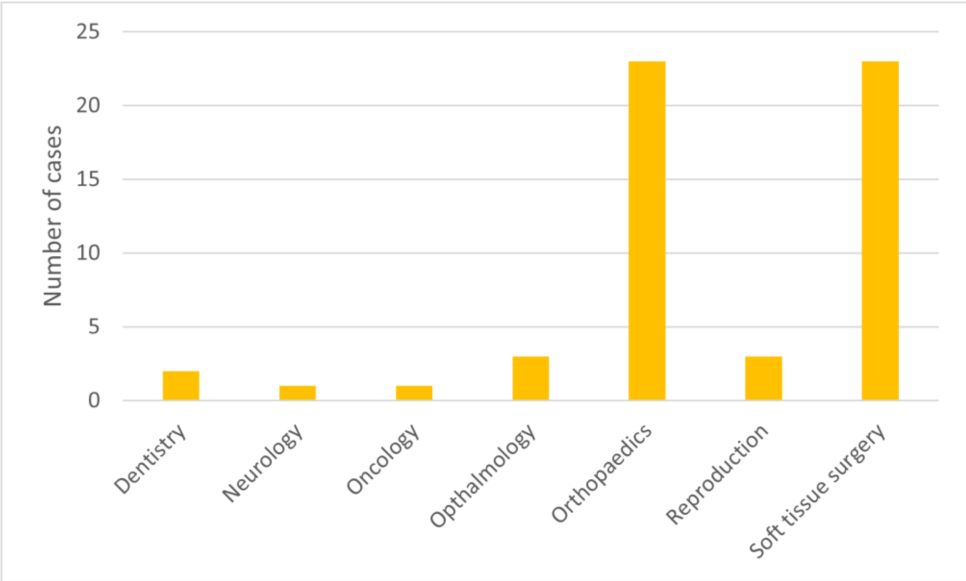

Figure 1 Representation of different indications fields for anaesthesia in SACs identified within the 36 case reports

Out of the 16 research studies 11 (68.8%) looked at general anaesthesia. Only two looked at sedation, including local anaesthesia (35,36) and two focused on analgesia besides reporting on the anaesthesia (37,38). One paper examined the efficacy of general anaesthesia and analgesia (39) and one publication presented results on sedation and analgesia (37).

Nine of the original research papers (56.3%) focused on alpacas, five (31.3%) on llamas and one (6.3%) on guanacos. However, one study (6.3%) included both llamas and alpacas (40) . Nine of the individual case reports (17.8%) were of llamas (41–49), while the rest of the publications (82.1%) included alpacas. The number of animals used in one of the original research papers ranged from 5 animals as the minimum, to 30 SACs as the maximum. Out of the 144 animals, 70.3% of these animals were male while 43 individuals were female. Nine studies only used male animals, three only included female animals and the rest had both male and female animals included in their study. Within the case reports the majority (60.7%) were female animals (n= 34/56) and 35.7% were male. Two reports did not mention the sex of the individual animal (41,48).

The animals' age, used for the original research studies ranged from 1 to 17 years and only one study used juveniles in their protocol (36). Out of all the animals identified in the case reports, 30 SACs were classified as adult and 26 were still juveniles. None of the animals within the case reports were classified as geriatric.

Each research study only included healthy animals in their population, whereas 39.3% of the SACs mentioned in the case reports were classified as “compromised”.

3.2. Anaesthesia in SAC

3.2.1. Pre anaesthetic considerations

Blood work

Most studies mentioned how the health status of the animals, which were used in their research was determined (62.5%). For some only a clinical examination was performed (35,39,50,51), while others combined a physical examination with routine blood chemistry (52–54). Complete blood count in addition to a routine clinical examination and serum biochemical analyses were used in three studies (38,55,56).

Case reports mentioned case specifically, which exams were undertaken. Unfortunately, six case reports (16.7%) on orthopaedic cases did not give any specific information about pre anaesthetic evaluations. Physical exams alone were mentioned in 12 reports (33.3%), while complete blood count, blood chemistry in addition to the clinical examination was evaluated for described cases in 18 reports (50%).

Fasting

Out of the 16 research papers ten (62.5%) made mention of fasting times with ranges from 2-48 hours for food and 0-12 hours for water. Five of the ten (50%) fasted the animals for 12 hours from food, two for 48 hours, one for 2 hours, 18 hours and 24 hours. The majority 40% (4/10) withheld water for 12 hours, two withheld water for 0 hours, one for 2 hours, 6 hours and for 8 hours.

Within the identified case reports, fasting was mentioned for 11 of the 56 (19.6%) patients with ranges from 12-48 hours for food and 0-8 hours for water. Of these 11 only five (45.5%) mentioned fasting from water as well. Three (27.3%) reported fasting food for 12 hours as well as another three (27.3%) mentioned fasting food for 24 hours. Two mentioned fasting food for the duration of 20 hours. There was only one reported case for each fasting 48 hours, 16 hours and 10 hours.

Fasting SACs before any anaesthesia also decreases the chances of bloat while simultaneously decreasing the risk of postoperative distress (23). In case appropriate times of fasting were not considered, regurgitation throughout the procedure is possible. Even salivation is continued throughout sedation or GA (22). Therefore, animals, which are not intubated, are more at risk to consequently suffer from aspiration pneumonia. Hence, fasting animals undergoing sedation or anaesthesia is highly recommended (24).

3.2.2. Sedation/ premedication

Since good pain coverage is necessary for a stable anaesthesia, additional pain medications are often given before, during or after any procedure requiring anaesthesia. Flunixin meglumine was the medication of choice in 25 of the 56 (44.6%) individual cases, applied at a dosage of 0.5-2.2 mg/kg IV or SC once a day or twice a day. However, the majority of animals received the medication IV, one animal received it SC. Six of the 56 animals (10%) received meloxicam at dosages ranging from 0.4 – 1 mg/kg IV, SC or P.O. Other medications belonging to the group of nonsteroidal anti-inflammatory drug given were carprofen or ketoprofen (Table 1)

Table 1 Analgesic drugs used in SACs the 36 identified case reports.

Analgesic drugs		
Nonsteroidal anti-inflammatory drug		
	Dosage (mg/kg)	Application
Flunixin Meglumine	0.5 – 2.2 SID/BID * 1 – 1.1	SC, IV
Meloxicam	0.4 – 1 SID * 0.5	SC, IV, per os
Ketoprofen	2- 2.5 SID	IV
Carprofen	0.7 – 3	IV
Opioids		
Butorphanol	0.05 – 0.1	SC, IV

(*) most commonly used dosage; SID once daily; BID twice daily

Xylazine

Xylazine can be given IV, IM as well as SC (22). However, IV administration tends to provide a more reliable result than the latter (22). Sedation occurs within 3 to 5 minutes after IV administration and only 10 to 15 minutes after IM injection (20). Its analgesic effects last only from 15-30 minutes whereas the overall sedative effect can last several hours (20). Common dosages from different sources can be seen in Table 2 (16,20,22,23).

Table 2 Xylazine, its recommended dosages and application, relevant practical and pharmacological details.

XYLAZINE IN LITERATURE						
Source	**Species**	**Dosage mg/kg**	**Administration**	**Onset (min)**	**Analgesia**	**Duration***
Aarnes et al., (20)	Llama, Alpaca	0.1-1.1	IV	5'	15'-30'	na
Aarnes et al., (20)	Llama, Alpaca	0.2-0.9	IM	10‘-15‘	15‘-30‘	na
Anderson et al., (57)	Llama	0.05 -0.4	IV, IM, SC	na	na	<40‘
Anderson et al.,(57)	Alpaca	0.1-0.5	IV, IM, SC	na	na	<40‘
Fowler et al., (16)	Unspecified	0.25 – 0.3	IV	3-5‘	15-30‘	60‘
Fowler et al., (16)	Unspecified	0.25 – 0.3	IM	10-15‘	15-30‘	60‘
Cebra et al., (22)	Unspecified	0.22-0.44	IV	na	na	na

*Duration refers to the extent of the sedative effect of the drug; na = not available.

Within the identified case reports four (7.1%) mentioned the use of xylazine in sedation protocols, while 22 of the case reports (39.3%) used xylazine alone or in combination with butorphanol, ketamine, ketamine and butorphanol as premedication for llamas or alpacas. A consistent dose of 0.1 mg/kg xylazine was used if the drug was applied IV (48,58–63). Depending on the drug combination, different dosages were used if applied IM. If xylazine was used as a sole premedication 0.1-0.5 mg/kg were used (43,46,64). In combination with ketamine alone 0.4-0.5 mg/kg (65,66) were injected, with butorphanol 0.13 mg/kg (45) and with both of the above-mentioned drugs xylazine was within the range of 0.3-0.46 mg/kg (49,60). It is reported, a higher dosage of xylazine combined with ketamine provided analgesia for up to 73 minutes in llamas and 52 minutes in alpacas (50,51,53) .

In the mentioned studies reduced heart rates as well as transient hypoxaemia was noted. However, the PaCO2 levels never exceeded 60mmHg demanding pressured ventilation. Despite noted bradycardia and low SpO_2 measures, the arterial blood oxygen saturation remained within physiologic levels (50). All of the above studies, which included xylazine in their anaesthetic protocols concluded that supplementary oxygen should be provided in clinical settings to support the animals during the transient hypoxemic state in the initial phase of the anaesthesia (50–53). In nine out of the 22 case reports (40.9%) no complications during anaesthesia were noted. However, within the other case reports, some complications were listed among which were bradycardia (42), hypothermia (61,66), hypotension (66) and the need for pressured ventilation (65). Despite some complications reported, the only two fatal outcomes reported among these cases were associated with their primary complaint and not with the anaesthesia (49,60). Unfortunately, six of these case reports did not mention whether any complications were noted during time of anaesthesia.

Detomidine

There seems to be a variation in sedation and restraint when using detomidine (20). Dosages IV or IM up to 0.04 mg/kg IV (16) are recommended for the use in llamas, while alpacas require higher amounts, up to 0.07 mg/kg to achieve comparable effects (20). Bradycardia has been noted at the dosage needed to achieve sedation (20). Other literature advises dosages of 0.01-0.06 mg/kg IM and 0.04 mg/kg IV (67).

One research study looked at the use of detomidine by comparing it with a newly developed detomidine paste for vaginal application (35) on alpacas. They used dosages of 0.02-0.07 mg/kg IV as well as 0.04-0.2 mg/kg intravaginally. They reported no complications however heart rates remained below baseline values at 60 beats per minute (35). Detomidine was not used in any of the 36 case reports.

Butorphanol

It is known, that butorphanol has commonly been used in camelids with minimal side effects (39). While a decrease in heart rate has been reported in llamas after IM administration (38), decreased blood pressure is more often associated with IV application. Significant changes in the animal's heart rate were not noted in two studies using butorphanol (39,68). However, throughout an isoflurane induced anaesthesia adult female alpacas showed decreased systemic vascular resistance, despite normal heart rates and normal blood pressure values (39). Reported hypoxaemia was associated with the GA not the drug itself (68), as well as reduced temperatures (39). Available data from published studies suggests that butorphanol is a safe sedative for the use in SAC without causing respiratory depression given at the dosage of 0.1 mg/kg IM or IV (38,39,69).

Findings of these literature search suggest that IV applications will reach higher plasma concentrations, up to 94ng/ml if given at 0.1 mg/kg IV, than IM applications (38). While the results of the study did not present clear results on the somatic analgesic effects of butorphanol the authors concluded that the visceral analgesic effect should be good based on the evaluated plasma concentrations (38). While the plasma concentrations are significantly higher after IV application, the bioavailability of the drug is still good if given IM (38).

In four cases (7.1%) butorphanol was used as a sedative, either alone (70,71) or in combination with xylazine (44,72) and in ten cases (17.9%) butorphanol was part of the premedication protocol, in combination with an alpha-2 adrenoceptor agonist, i.e. xylazine (45,46,49,60,62,71–73). In some cases, ketamine was added to the protocol as well (49,60). The dosages used in alpacas ranged between 0.05-0.2 mg/kg IM/IV (46,60,62,71–74) and in llamas 0.01-0.1 mg/kg IM/IV (45,46,49). In seven cases no complications under anaesthesia were reported. Two animals had to be euthanized on the surgery table due to their presenting disease (49,60). However, the recovery after anaesthesia was normal and without any further complications (72).

Ketamine

Table 3 Ketamine, its recommended dosages and application, relevant practical and pharmacological details.

KETMAINE						
Source	**Species**	**Dosage mg/kg**	**Administration**	**Onset (min)**	**Analgesia**	**Duration***
Cebra et al., (22)	Un-specified	1.3-1.75	IV	na	na	na
Fowler et al., (16)	Un-specified	1-4	IV	na	na	na
Fowler et al., (16)	Un-specified	1-8	IM	na	na	na
Lin et al., (67)	Un-specified	1-5	IM, IV	na	na	na

*Duration refers to the extent of the effect of the drug. Na = not available.

Research studies using ketamine, combined the drug with different anaesthetic agents, such as alpha-2 adrenoceptor agonists, benzodiazepines, propofol and opioids, many drugs which are not licensed in Europe (Table 4) (32,51–53,69,75). The highest dose was recorded for alpacas at 12 mg/kg IM in combination with xylazine (53). DuBois's research, which evaluated a similar anaesthetic protocol used much lower dosages for llamas (4 mg/kg and 8 mg/kg) (52). Guanacos received ketamine at a dosage of 2.7 mg/kg together with medetomidine and butorphanol (69). All studies using an alpha-2 adrenoceptor agonist in their anaesthetic protocol with ketamine noticed decreased heart rates and hypoventilation at some stage.

Table 4 Anaesthetic protocols from identified case reports using ketamine in combination with other anaesthetic drugs.

Author	Species	Drug(s)	Dosages	Application
duBois et al., (52)	Llamas	Ketamine + Xylazine	4 mg/kg; 0.4 mg/kg 8 mg/kg; 0.8 mg/kg	IM IM
Gadeyne et al., (75)	Llama	Ketamine + Medetomidine Ketamine + Dexmedetomidine	5 mg/kg; 0.02 mg/kg 5 mg/kg; 0.01 mg/kg	IM IM
Georoff et al., (69)	Guanaco	Ketamine + Medetomidine + Butorphanol	2.7mg/kg; 0.09 mg/kg; 0.3 mg/kg	IM
Prado et al., (53)	Alpaca	Ketamine + Xylazine	8 mg/kg; 0.8 mg/kg 12 mg/kg; 1.2 mg/kg	IM IM

Six out of the 56 (10.7%) case reports used ketamine in their premedication protocols. The drug was combined with an alpha-2 adrenoceptor agonist (i.e. xylazine or medetomidine) (65,66,76) and in two cases butorphanol was added to the protocol as well (49,60). 5 mg/kg IM were given to animals (i.e. alpacas) in combination with xylazine or medetomidine. These animals didn't receive any additional induction agent before intubation. In one case, one alpaca received 3 mg/kg ketamine IM as premedication with xylazine (0.4 mg/kg) IV for induction (66). Following the use of these protocols for most animals no complications were reported. Hypothermia at the end of a three and a half hour-long general anaesthesia was noted for the alpaca receiving two dosages of ketamine at 3 mg/kg IM and IV (66). While the anaesthetic recoveries were uneventful, three out of the four cases had to be euthanized due to complications resulting from their primary complaint (65,76). Two were fracture related and the other one was diagnosed with neoplasia. Two cases receiving butorphanol together with ketamine and an alpha-2 adrenoceptor agonist (47,49) had to undergo exploratory laparotomies. However, due to their presenting complaint both animals had to be euthanized during the procedure.

3.2.3. Local anaesthesia

Local anaesthetics utilized in the identified studies and case reports were lidocaine, bupivacaine and mepivacaine, which are in general the most common drugs used in the veterinary field (22). (26)Onset of action of lidocaine is within 1-2 minutes (22,23) and lasts for approximately 60 – 120 minutes (22,23). The total dosage should not exceed 5mg/kg in alpacas or llamas (25) and is advised to be used between 2-4mg/kg (22).

For the use as an epidural, lidocaine can be used alone or in combination with anaesthetic drugs such as, xylazine, ketamine or opioids (20,25,36). If used as an epidural in the sacrococcygeal intervertebral space, 0.22mg/kg are recommended for llamas and alpacas (24). The dosage should not exceed 1ml/50kg, otherwise the effect of the drug could desensitize the sciatic and femoral nerve and lead to recumbency (25). Lidocaine, given at 0.22 mg/kg into the epidural space can be combined with xylazine at 0.17 mg/kg (20). Aseptic preparation of the area is essential to avoid infections into the intervertebral space (25). Effect of the application can be expected about 60 seconds after the injection in the intervertebral space and can be seen in the relaxation of the tail (22,25).

A clinical evaluation of caudal epidural anaesthesia for the neutering of alpacas found that adequate desensitisation of the spermatic cord was not observed with any of their treatment regimens (36). Neither 1.5 ml lidocaine 2%, or a combination with xylazine 20 mg IM or a 1:1 use of lidocaine and xylazine (0,75ml) into the epidural space together was sufficient to provide analgesia for the scrotum and spermatic cord. All animals needed local lidocaine into the surgical site to provide relief from the experienced discomfort. Other literature recommends the application of 2ml lidocaine 2% into the testis in addition to 2ml subcutaneous lidocaine into the incision site for sufficient analgesia (20).

From the case reports using local anaesthesia (21 cases), seven (33.3%) performed an epidural (46,60,77,78).

Regional nerve blocks have not been used regularly on SACs due to the lack of documentation of the anatomical course of their nerves which varies from other livestock species (20). The thickened skin and fibres of the camelid neck make jugular venipuncture challenging to a certain degree (22). Thus, in some studies a local anaesthetic was used to place an intravenous catheter by making a small incision in the skin to easier facilitate the administration of xylazine as well as other drugs (24).

Only two cases used lidocaine (61,66) as a local anaesthetic. Lidocaine 2% was used to anaesthetise the femoral and sciatic nerves using a 4mg/kg dose (66). They concluded that the sciatic femoral nerve block with lidocaine did provide partial analgesia(66).

None of the literature described complications due to local anaesthetics.

3.2.4. Induction and maintenance

Ketamine is the only licensed anaesthetic drug for induction in SACs in European union (26). For 32 cases (57.1%) ketamine was added to the induction protocol. All animals received the induction dosage IV, varying from 1 mg/kg to 5mg/kg. Among the reported complications during GA were tachycardia (72), bradycardia (77), hypoxaemia (77,79) and hypothermia at the end of anaesthesia (61,66). One Alpaca undergoing a mandibular symphysiotomy developed neurological symptoms post-surgically due to hypercapnia and a respiratory acidosis. The animal recovered after 24 hours (80). None of the other animals suffered any complications post-surgically due to the anaesthesia.

To allow administration of inhalant anaesthetic gases to maintain the desired anaesthetic plane, especially in procedures longer than 20 minutes, endotracheal (ET) intubation is necessary (20). Using endotracheal tubes, facilitates not just the administration of anaesthetic gas or supplemental oxygen, but intubation also reduces the risk of regurgitation and aspiration pneumonia (22). Intubation in SACs has to be done while they are in sternal recumbency, to allow better visualization of the species-specific anatomy, that make intubation more complicated in these animals (Figure 2) (23,24).

Figure 2 Lateral radiograph of a llama in Niehaus et al., showing the elongated oropharynx (with (A) soft palate and (B) epiglottis) in the species (21).

Head position

According to literature, the head of the animal should be in a position that supports drainage of saliva throughout any procedure (22). The pharynx should be elevated above the mouth opening before intubation thus sternal recumbency is the position of choice before intubation (20). If subsequently another position is needed for surgery like dorsal or lateral recumbency, it is advised to tilt the head of the sedated animal in such a manner to ensure the outflow of saliva from the mouth in case no ET is placed (22). Nine out of the 16 (56.3%) research papers made mention of the position of the animals during the anaesthetic procedures. Five of these (56%) were placed in left lateral recumbency. In two studies the animals were placed in right lateral recumbency and one in sternal recumbency. One study left the animals in lateral recumbency without mention of which side. 22 out of the 56 (39.3%) animals from the case reports were placed in dorsal recumbency, four in left lateral recumbency, two in right lateral, two made no distinction in which lateral position and 4 were placed in sternal recumbency. The position of the case reports was associated with the relevant surgical procedure caried out on the animal.

Maintenance

Only two research papers (12.5%) identified in this literature search looked at inhalation anaesthetics (40,81). One of them used isoflurane for induction at vaporizer setting of 5% and for maintenance at 2% in llamas (81). Recovery was quiet and uncomplicated and while no complications were observed, an increase in heart rate, a decrease in mean arterial pressure as well as an increase in partial pressure of carbon dioxide was noticed with an increase of the isoflurane level (81).

In 38 (67.86%) case reports isoflurane was used for maintenance. Only two mentioned the percentage of isoflurane given. One was at 0.6-0.8% end-tidal concentrations (77) and the other at 1.6 +/- 0.1% end-tidal concentrations (72). Three of the case reports still used halothane at nonmentioned doses (42,63,82). Four cases used sevoflurane (61,76,79) with also only one mentioning the dosage given at 2% vaporizer setting (79). However, 21.4% of cases failed to mention which drug or anaesthetic gas was used for GA maintenance.

Monitoring

In cases, where GA is performed by constant delivery of an anaesthetic drug, whether IV or as inhalant gas, more extensive monitoring, such as end-tidal carbon-dioxide concentrations, arterial blood pressure and other parameters evaluating cardio-respiratory performance, is necessary (16,20,22,67) (Table 5).

Table 5 Physiologic values of cardiorespiratory parameters in SAC according to identified literature (16,22,23)**.**

Parameter*	Value
Temperature	37.5-38.9°C
Pulse	60-90/min
Respiratory Rate	10-30/min
SAP/MAP/DAP	60-135/70-100/45-95
$EtCO_2$	40-50

*SAP, systolic arterial pressure, MAP, mean arterial pressure, DAP, diastolic arterial pressure, $EtCO_2$ end-tidal carbon dioxide

All research papers (16) mentioned which individual parameters were monitored during the anaesthetic period (Table 6) and ten out of the 36 (27.8.0%) case reports mentioned the parameters for which data was recorded. One case report specifically mentioned the monitoring of mucus membrane colour and capillary refill time during GA in addition to the listed parameters in Table 6 (76). Nine of the research papers added the time interval in between each monitoring cycle, which were either 5 minute-, 10 minute- or 15 minute-intervals between their recordings. Two of the case reports added this information, stating that values were recorded every five minutes (32,68).

Table 6 Listed parameters monitored in identified literature. While all of the research papers mentioned the individual parameters, it was less than 30% of the case reports (42,65,70,72,73,76,77,79,80,83), that included which parameters were monitored throughout GA. The percentages in this table refer to the sources that do mention monitoring parameters.

Parameter*	16 Scientific article (%)	10 Case reports (%)
HR	82%	70%
RR	76%	60%
C°	47%	50%
SpO2	47%	60%
ECG	59%	60%
non-invasive BP	41%	40%
invasive BP	29%	50%
EtCO2	41%	70%
EtISO	24%	30%
Blood gas analysis	59%	20%
Cardiac output	12%	-

*HR heart rate; RR respiratory rate; C temperature (rectal, oesophageal); SpO2; ECG electrocardiogram; BP blood pressure; EtCO2 end-tidal carbon dioxide concentration; EtIso end-tidal isoflurane concentration.

Study specific relevant time periods relating to the anaesthesia progression and recovery were published by 11 out of the 16 studies (68.8%) (Table 7), however not all of the studies used the same time frames, e.g. "time from drug administration until …", but defined study-specifically which time period was monitored, e.g. “time from extubating until standing”. Similarly, seven case reports (19.4%) mentioned the time from drug administration until recumbency, while the total procedure time was recorded for ten case reports (27.8%). Additionally, nine case reports (25.0%) added information about the recovery time.

Table 7 Number of studies (in percentage) reporting time durations of the different anaesthetic periods

Monitoring of times	Studies
Time from injection until detectable sedative effect	24%
Time from injection until sternal recumbency	29%
Time from injection until lateral recumbency	24%
Duration of anaesthesia	29%
Duration of analgesia	12%
Time from sedation until extubation	12%
Time after anaesthetic intervention until sternal recumbency	29%
Time after anaesthetic intervention until standing	53%
Duration of lateral recumbency	18%

3.2.5. Recovery

While 25% of the found published cases reported uneventful recoveries, 5 animals were euthanized (8.9%), one of them directly on the table (49), the other four later due to complications in the recovery period (46,60,76) . Reason for euthanasia, however, was related to the initial presentation, not the anaesthesia. Meanwhile, 42.9% of the case reports did not make any specific statements regarding anaesthesia related complications or recovery.

3.2.6. Complications and side effects

SACs are known as obligatory nose breathers (20), therefore, if their head is positioned too low, nasal oedema can occur and is reported as the most common complication, which can cause stress during the recovery period (22). Elevating the head over heart level while the animal is still recumbent can decrease the risk of oedema to develop in the first place. Additionally, nasal tubes can be placed to support the animal in the recovery phase if oedema was noticed (21). However, the oedema resolves quickly once the head is kept up again. None of the identified studies, or case reports mentioned the occurrence of nasal oedemas during GA.

In 62.5% of the research studies one or more complications which are discussed with their relevant drugs were mentioned. The most commonly noted complication during anaesthesia in the identified papers was hypoxaemia (50–54).

Other issues, such as hypoglycaemia and hypothermia are more common in young animals (20,22) and should be considered and countervailed with appropriate support throughout anaesthesia (19).

4. Discussion

This study aimed to collect data on anaesthetic drugs, which are licensed for the use in SACs and the general management of anaesthesia in these animals, including criteria for an anaesthetic intervention, considerations prior to anaesthesia, possible complications, and recovery. The highlighted drugs are in agreement with European legislation for food producing animals. A literature search was conducted to identify relevant publications, including books, research papers and case reports, which made use of anaesthetic protocols in clinical settings in SACs.

Most of the research has been done in the USA. The highest number of case reports also originated in the USA. However, almost 70% of the identified case reports were from other countries. This increases the variety of drugs reported to be used in anaesthesia as different countries have different regulations regarding the usage of drugs in SACs. While the EU legislation (26) clearly defines which drugs are listed for the use in SACs, in the USA the FDA (Food and Drug Administration) regulates which substances might be used. At this point, only extra-label use of drugs is possible since no drugs are listed for camelid species (84). Most studies use combinations of different anaesthetic drugs, therefore discussing only the use and effects of licensed drugs according to the EU legislation is difficult.

While 29.4% of studies were focusing on the cardiopulmonary effect of drugs on SACs, 31.5% of studies evaluated the pharmacokinetics and dynamics of specific drugs. Additionally, a small number of studies considered analgesic efficacy of anaesthetic protocols. Since several drugs have not been studied in detail in the species yet, there is still need for further research in these areas to generate knowledge on efficacy and safety of commonly used drugs in SACs.

The majority of studies as well as case reports were on alpacas, while only a small number of studies and case reports were on llamas. Even though there was one study identified which included guanacos in the study population, no case report on this species was found within this study. The difference in the representation of species in the numbers of studies and case reports could be due to differences in population distributions in the countries of study origin. Studies from Switzerland, the United Kingdom, Austria and Germany all had higher numbers of alpacas than llamas (5–8) A reason that there was no case report found on guanacos could be explained, by the fact that it is one of the wild species (16,85).

While two thirds of the animals used in the identified studies were male, only a third of the animals in the case reports were male. The majority of animals in registered populations in different countries are female (2,3,5). SACs are herd animals (57) and are hence found to have larger groups of females whereas males make out the minority of a herd. Since many SAC holders keep the animals for breeding purpose (2,3), the populations of owned SACs therefore consist of more female animals. However, female animals are more valuable than male individuals. It is possible that this could contribute to the fact that more male animals are used in research studies.

Only adult animals were included in the identified studies, while about 45% of the identified cases reports were juvenile, up to 12 months old, animals. The case report did not include any geriatric animals, while two studies included animals up to the age of 17 (55,69) in their study population. Considering the age distribution in SAC populations, a study on necropsies in alpacas saw that a third of the animals under investigation were 1-5 years of age (12). Only 9% of the animals were over the age of 10 (12), which are similar figures compared to a study from Germany (5). Therefore, the age distribution of the SACs identified in this literature search seems to be representative for the general population.

All adult animals included in the studies were classified as healthy. To obtain comparable results for the anaesthetic research questions, it is understandable that only healthy animals were considered. However, in clinical settings usually animals with symptoms are treated, hence more than a third of the case reports classified the patients as "compromised". Since studies were only done on healthy animals, it is difficult to derive whether the results on safety and efficacy of the drugs would apply in the same way. (24). Even though xylazine is known for its cardiorespiratory side effects (20,31), the drug was still used for 18% of the compromised patients. However, xylazine is essential, since the EU legislation has strict regulations on licensed drugs in SACs. Statistical evaluation of monitored parameters in compromised animals in association with the applied drugs would be helpful to establish guidelines on safe anaesthetic drugs to use in such cases.

Fasting animals before anaesthetic procedures has been recommended by several sources (16,20,23,31). The majority of studies mentioned fasting time for food and/or water. Of these only one study reported fasting times of 2 hours which were not within the recommendation set out by literature (35). Reasons for the shortened fasting times were not given. However, according to the authors, the animals did not suffer from associated complications, such as aspiration pneumonia (35). Less than 20% of the case reports mentioned whether animals were fasted. Even though the majority of identified case reports, did not state whether animals were fasted before GA, no mention was made of post-operative complications, if recommendations regarding fasting of feed and water were not observed. Aspiration pneumonia as a possible complication due to regurgitation (20,31,86), was not mentioned for any of the identified publications.

While many research papers and case reports mentioned the positioning of animals during GA, the position during anaesthesia is not as important as the positioning during intubation (31). Additionally, no mention was made about the positioning of the head during any of the procedures to compare if they followed the advice from literature (31). None of the studies or case reports mentioned associated complications such as regurgitation or aspiration pneumonia, therefore, one cannot make any conclusions on the importance of the head positioning. However, since SACs are obligate nasal breathers, this should always be considered when performing a GA and as well during the recovery period (22).

Within the identified published case reports, monitoring of individual parameters throughout anaesthesia had a low percentage of transparency of these parameters. Just over a quarter of identified case reports, mentioned individual parameters that were recorded throughout the GA. It can be seen that more invasive monitoring was found in published research studies, since the studies focused more specifically at understanding the cardiovascular or antinociceptive effects of the drugs. Good monitoring throughout anaesthesia aids to counteract and avoids complications, i.e. hypoventilation, which can occur throughout GA. A half of the research studies reported on the time until the animals were able to stand, only 12% shared information on the duration of anaesthesia. Since different anaesthetic protocols were applied, direct comparison of time and durations would not be possible. However, extensive monitoring under the consideration of the animal's condition and the conducted procedure should be planed thoroughly (31). Side-effects, such as respiratory-depression, of used drugs should be known beforehand. Additionally, age-related a species-specific risk factors have to be considered before GA to provide appropriate support.

Since almost a half of case reports, did not include information on complications throughout GA or post surgically, only limited interpretations on common complications are possible. Only 25% of the case reports shared the time until recovery, which was not standardized. However, the majority of these animals recovered within the first hour. Some animals however recovered only within 24 hours post-anaesthesia (80). Conclusion about the reported recovery times can't be deducted, since the initial indication for GA and the applied anaesthetic protocols differed between the individual cases. About 25% of cases had uneventful recoveries, while 16 % were euthanized due to their initial presenting complaint and not because of complications associated to the anaesthetic drugs. Details on the recovery set-up or monitoring throughout recovery are not readily available, therefore conclusions on improvement or considerations during the recovery period can't be deducted. Reasons for euthanasia were e.g. pleural effusions, additional fractures, damaged ureters. Better transparency in published case reports on complications or altered parameters throughout anaesthetic procedures would allow for improved comparison and conclusions.

Xylazine was used in four research studies and in a third of the case reports. One research study applied a dosage of 1.2 mg/kg (53), which exceeded the recommended dosages found in published literature (16,23,31). Lateral recumbency with active analgesic effect for 30 minutes was achieved at a dosage of 0.8mg/kg IM in llamas, which should be sufficient for most standard procedures (52). Veterinarians in the field should however consider that alpacas require higher dosages than llamas to achieve the same effect (53) . The animals receiving the higher dosage (1.2mg/kg) had a smooth recovery from anaesthesia, even though two of the animals showed transient severe hypoxaemia, which resolved again. However, in all identified studies, using xylazine reduced heart rates as well as the previously mentioned transient hypoxaemia was seen in the animals, which correlates with the effects of xylazine according to literature (50,51,53). Additionally, bradycardia was seen with correlating low transient SpO_2 measures (50). In the case studies bradycardia (42), hypothermia (61,66), hypotension (66) and the need for pressured ventilation (65) was associated with xylazine use, which correlates with the known effects of the drug (20,31). Although these changes were observed none of the animals died due to any of them. The increased risks of complications, that stems from the use of detomidine in comparison to xylazine (16,31) could be a reason, why it has not been used in any of the case reports. The available literature allows to conclude that xylazine should therefore be preferred in SACs.

While ketamine is the only licensed induction drug in the EU, general literature fails to provide information on the onset of action, duration of analgesic effect and duration of effect (16,22,67). Ketamine was used in one research paper at above recommended dose of 12 mg/kg IM in combination with xylazine (53). No specific complication associated with ketamine was mentioned for this study. All studies using an alpha-2 adrenoceptor agonist in their protocol with ketamine noticed decreased heart rates and hypoventilation, which can be due to the applications of the alpha-2 adrenoceptor agonist. This could be attributed to the use of ketamine, as literature mentions that ketamine can cause apnoea (16). Only one study made mention of mild ataxia post GA, which could be a consequence of ketamine, as it is a known complication (16). Hypothermia at the end of the anaesthesia was noted for an alpaca receiving two dosages of ketamine at 3mg/kg IM and IV (66). However, the animal also received xylazine which could contribute to the hypothermia, as well as the long procedure time (205 minutes) being the reason for the hypothermia (16). While the majority of the anaesthetic recoveries were uneventful, three out of the four cases had to be euthanized due to complications resulting from their primary complaint. Since ketamine was also included in the majority of the compromised cases, one should further assess the safety of the drug in compromised SACs.

Butorphanol as the only opioid approved for the use in SACs in Austria, showed to have varied effects between individuals and lead to sedation or excitement using the same dosage (0.1 mg/kg IM/IV) (38). Some animals did not show any signs of sedation after receiving a dosage of 0.1 mg/kg IM (68). In calves receiving just butorphanol excitement was noted 10 minutes after injection, while combined use with an alpha-2 adrenoceptor agonist provided sedation (87). Butorphanol without additional anaesthetic agents seems not to have the best analgesic properties as stated by literature (31). Recommended protocols from literature where not exceeded in the identified studies (20,23). Vasodilation, a side effect after the application of butorphanol (39), was seen in a study that reported decreased heart rates after IM administration in llamas (38). However, alpacas receiving the opioid were observed to still have normal heart rates and normal blood pressure values (39). This could indicate that species specific differences should be further evaluated.

The following conclusion based on this literature research can be made: Xylazine (0.4-1.2 mg/kg IM) in combination with ketamine (4-12 mg/kg IM) was safe to be used in llamas at the lower end of the range and in alpacas even in higher dosages (50,54). However, it is important to note, that all authors advised to have supplementary oxygen available. Butorphanol at 0.1 mg/kg IM or IV should have minimal side effects on the animals (38) and has been used in this dosage in 10 cases either as sedative or premedication.

The benefit of local anaesthetics to reduce the need for systemic anaesthetic drugs is known (20,23). Epidurals as local anaesthesia was used in one third of cases mentioning the use of local anaesthetics. Lidocaine was not used for an epidural in any of the identified studies. This could be due to the longer efficacy and effect of the used drugs compared to lidocaine (88). In general, lidocaine alone was only used in two cases for a local analgesia (61,66). However, according to the legal regulations, only lidocaine and not any of the other mentioned drugs may be used in SACs in Austria (26).

Limitations of this literature research comprise the that the literature research was only made in English. A multilingual approach could increase the number of considerate publications. Considering Spanish and German papers could have been beneficial.

Sound knowledge on different drugs and handling is paramount to provide gold standard medical care. Unfortunately, the results of this study reveal that published data on anaesthesia in SACs sparse and incomplete. Many reported protocols are a combination of drugs which are not licensed for the use in SACs in Europe. Therefore, conclusion on recommendable dosages is difficult, since other drugs, such as guaifenesin, or benzodiazepines are used for induction, thus making it difficult to derive conclusion on safe to use protocols for veterinarians in Austria. Protocols using an alpha-2 receptor agonist, xylazine in combination with butorphanol and/or ketamine, appear to be safe in healthy animals but there is a lack of information regarding safe dosages, pharmacokinetics, and pharmacodynamics, especially in compromised animals. Therefore, only limited conclusions can be drawn about which drug combination is most appropriate in compromised SACs. Consequently, this topic still needs to be investigated in detail.

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6. Tables and Figures

Tables

Figures

Abbreviations

ET	Endotracheal
GA	General anaesthesia
IV	Intravenously
IM	Intramuscularly
MAC	Minimal alveolar concentration
NDMA	N-methyl-D-aspartate
SAC	South American Camelid
SC	Subcutaneously
UVMV	University of Veterinary Medicine Vienna

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